Big Data and Computing Visions

www.bidacv.com

Big. Data. Comp. Vis. Vol. 4, No. 4 (2024) 257–271.

Paper Type: Original Article

A Study on Fuzzy Cognitive Maps Using Fuzzy Inference System

Appasamy Saraswathi[1,*], Seyyed Ahmad Edalatpanah[2], Sanaz Hami Hassan Kiyadeh[3]

[1] Department of Mathematics, SRM Institute of Science and Technology, Kattankulathur – 603 203, Tamilnadu, India; saraswaa@srmist.edu.in.
[2] Department of Mathematics, Ayandegan Institute of Higher Education, Tonekabon, Iran; saedalatpanah@gmail.com.
[3] Department of Mathematics, The University of Alabama, Alabama, USA; shkiyadeh@crimson.ua.edu.

Citation:

Received: 07 April 2024 *Revised: 09 June 2024* *Accepted: 11 July 2024*	Saraswathi, A., Edalatpanah. S. A., & Hami Hassan Kiyadeh, S. (2024). A study on fuzzy cognitive maps using fuzzy inference system. *Big data and computing visions,* 4(4), 257-271.

Abstract

Fuzzy Mathematics theory has been studied extensively in this study. Most early interest in fuzzy set theory pertained to representing uncertainty in human cognitive processes. Fuzziness can be found in many areas of daily life, such as engineering, business, medical and related health sciences, and the natural sciences. It is particularly frequent, however, in all areas in which human judgment, evaluation and decisions are important. However, in many real-life cases, the decision data of human judgments with preferences are often vague, so the traditional ways of using crisp values are inadequate. Due to a lack of information, the future state of the real system might not be known completely. Fuzzy mathematical modelling represents a real-world problem in a mathematical form to find solutions to the problem that correspond closely to how humans perceive it. Also, fuzzy modelling increases the validity of ill-structured systems by offering a deeper understanding of the complexities of decision parameters. In this paper, we analyze the problem of the transgender using FCMs and Combined Fuzzy Cognitive Maps (CFCM). This paper is divided into five sections. Section one introduces the basic introduction of transgender and the previous research of Fuzzy Cognitive Maps (FCM) and Combined FCM. Section two introduces FCM and combined FCM and the basic operations. Section three shows the basic definitions of FCM and Combined CFCM. The fourth section provides methods to analyze transgender problems using combined FCM. The final section gives the conclusions and some suggestions based on our study.

Keywords: Unsupervised transgender, Fuzzy sets, Fuzzy cognitive maps, Hidden patterns, Decision making and optimization, Fuzzy inference system.

1 | Introduction

1.1 | About Transgender

Nature has given the third gender to the world. In Hinduism, these people are treated as equals to god. The changes in these people are due to hormone disorders. Every child by birth will be male or y to female. As

Corresponding Author: saraswaa@srmist.edu.in
https://doi.org/10.22105/bdcv.2024.482326.1212

they grow up, hormonal changes take place and make them transgender. Transgender people are called Hijras in India and are often discriminated against in jobs, forcing them to resort to begging and prostitution in Koovagam (April/May) for an annual festival which takes place for fifteen days.

Tamil Nadu has an estimated population of 30,000 transgender people. It has made great strides in trying to integrate transgender people into society. This includes welfare schemes initiated by the government and the acceptance of transgender people into the mainstream media and film industry. Parents should realize and accept their feelings. However, the parents who accept physically challenged kids are not ready to accept these kids wholeheartedly. Parents feel ashamed of those persons and push them out of their families. As they are pushed out of their families, they encounter many societal problems. They are ignorant of the causes of their status.

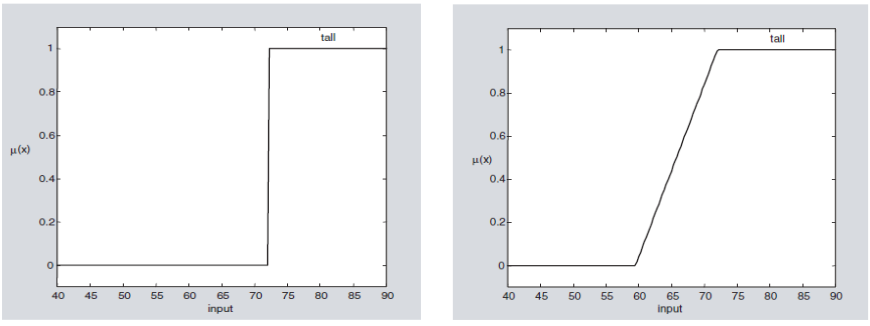
Their family members, as well as the community around them, are also ignorant of the real cause of their status as transgender. The parents and family members feel ashamed of having given birth to such a child. They feel it is a curse from God. As a result, they are pushed out of the family at one point. As a result, they remain as illiterate, ignorant, homeless, jobless and pushed to beg or be involved in sex work to earn their living.

The policemen, their daily requirements, who are given the authority to safeguard such a vulnerable section of society themselves, misuse these people to satisfy their animal pleasure. Due to a lack of knowledge on protected sex, they fall prey to deadly diseases such as HIV/AIDS, etc. Even the government has not given any proof of identity. That is required to get admission to school, get employed, get an adult franchise, get rehabilitation measures from the government, etc. As a result, they live a degraded life of depression and trauma, depending on begging and prostitution to meet.

1.2 | Fuzzy Cognitive Maps

Fuzzy Cognitive Maps (FCMs) can successfully represent knowledge and human experience and introduce concepts to represent the essential elements and the cause-and-effect relationship among the concepts to model the behaviour of any system. It is a convenient, simple, and powerful tool used in numerous social, economic, educational, political, medical, and technical fields. The FCMs work on the opinion of experts. FCMs model the world as a collection of classes and causal relationships between classes. FCMs are signed and directed graphs with feedback. The directed edge C_{ij} from causal concept C_i to concept C_j measures how much C_i causes C_j. Here C_i, … C_n are concepts or nodes of FCMs. The edge weights or causalities C_{ij} are taken from the set {-1, 0, 1}. The directed graph is drawn using edge weights e_{ij}. The Matrix E is defined by $E = (e_{ij})$, where e_{ij} is the weight of the directed edge C_iC_j. E is called the adjacency matrix of FCM. It will work as a dynamical system to identify the joint effects of all the interacting fuzzy knowledge from Experts.

Cognitive Maps are techniques that attempt to depict and analyze the cognitive process of human thinking and behaviour on specific domains by creating models. These models are represented by assigned directed graphs of concepts and by the various casual relationships that exist between the concepts.



a. **b.**

Fig. 1. Fuzzy membership; a. crisp membership function, b. fuzzy-membership.

(a) In 1965, Zedah [1] proposed FCM based on his fuzzy sets. In a crisp set, membership or non-membership of element' x' in set $\mu_A(x)$, where $\mu_A(x)=1$ if $x \in A$ and $\mu_A(x)=0$ if $x \notin A$, A is described by a characteristic function; Fuzzy set theory extends this concept by defining partial membership. A fuzzy set A on a universe of discourse U is characterized by a membership function that $\mu_A(x)$ takes values in the interval [0, 1].

Uncertain causal knowledge is stored in FCMs. FCMs are fuzzy signed digraphs with feedback. The sign (+ or -) of FCM edges indicates a causal increase or decrease. A number in [−1, 1] indicates the fuzzy degree of causality. FCMs learn by modifying their causal connections in sign and magnitude, structurally analogous to how neural networks learn. An appropriate causal learning law for inductively inferring FCMs from time-series data is the differential Hebbian law, which modifies causal connections by correlating time derivatives of FCM node outputs. The differential Hebbian law contrasts with the output-correlation learning laws of adaptive neural networks.

FCM nodes represent variable phenomena or fuzzy sets. An FCM node nonlinearly transforms weighted summed inputs into numerical output, again in analogy to a model neuron. Unlike expert systems, which are feed-forward search trees, FCMs are nonlinear dynamical systems. FCM resonant states are limit cycles or time-varying patterns. An FCM limit cycle or hidden pattern is an FCM inference. Experts construct FCMs by drawing causal pictures or digraphs. The corresponding connection matrices are used for inference. By additively combining augmented connection matrices, any number of FCMs can be naturally combined into a single knowledge network. The ith expert's credibility wi in [0, 1] is included in this learning process by multiplying the i^{th} expert's augmented FCM connection matrix by w_i. Combining connection matrices is a simple type of adaptive inference. An unsupervised learning law, such as the differential Hebbian learning law, generally modifies connection matrices. Under special conditions, differential Hebbian dynamical systems are proved globally stable: they resonate on fixed-point attractors.

FCMs are more applicable when the data in the first place is an unsupervised one. The FCMs work on the opinion of experts.FCM has a major role, mainly when the data concerned is unsupervised. Further, this method is the most simple and effective as it can analyze the data using directed graphs and connection matrices. FCMs model the world as a collection of classes and causal relations between classes, which was introduced by Kosko [2] in the year 1986. It is a very convenient, simple, and powerful tool used in numerous fields such as social, economic, medical, etc., illustrated by Kandasamy et al. [3].

1.3 | Properties of FCM Matrix

Let $C_1, C_2 \ldots C_n$ be causal concepts and let $e_{ij}=e(C_i,C_j)$ be the causal edge function value, the amount of causality C_i imparts to C_j. For a Cognitive map, $e_{ij}=0,1$ or -1.

Letb $E=(eij)_{1\le i,j\le n}$, represents the matrix of causal edge values for the given FCM.

Suppose the FCM is a cognitive cognitive map. Then, E is an adjacency matrix. It lists all one-edge paths on the cognitive map.

$E^2=[eij^2]=$ ExE lists all two-edge paths on the cognitive map.

$$e_{ij}^{(2)} = \sum_{k=1}^{n} e_{ik} \times e_{kj},$$

is non-zero if there is a k such that e_{ik} and e_{kj} are non-zero. Similarly, $E_3, E_4 \ldots E_{n-1}$ list the effect of summing all three-edge, four-edge ... n-1 edge indirect effects.

Then the total-effect matrix T is the sum of the powered matrices E^i.

$$T = \sum_{i=1}^{n-1} E^i.$$

If the above process is repeated with E replaced E bar, the matrix of absolute values of absolute values of E, then $ebar_{ij}^{(k)}$ is non-zero if and only if there are $ebar_{ij}^{(k)}$ many k-edge paths from C_i to C_j. Such information is useful when searching for forward and backward chains.

1.4 | Truth Values of Fuzzy Logic

A basic application might characterize sub-ranges of a continuous variable. For instance, a temperature measurement for anti-lock brakes might have several separate membership functions defining particular temperature ranges needed to control the brakes properly. Each function maps the same temperature value to a truth value in the 0 to 1 range. These truth values can then be used to determine how the brakes should be controlled.

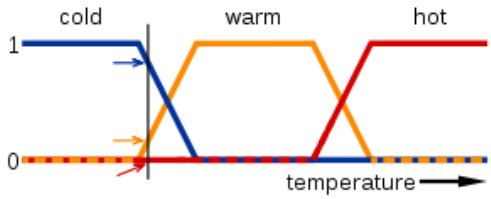


Fig. 2. Fuzzy logic temperature.

In this image, the meanings of cold, warm, and hot expressions are represented by functions mapping a temperature scale. A point on that scale has three truth values one for each of the three functions. The vertical line in the image represents a particular temperature that the three arrows (truth values) gauge. Since the red arrow points to zero, this temperature may be interpreted as not hot. The orange arrow (pointing at 0.2) may describe it as slightly warm, and the blue arrow (pointing at 0.8) is fairly cold.

1.5 | Fuzzy Inference System

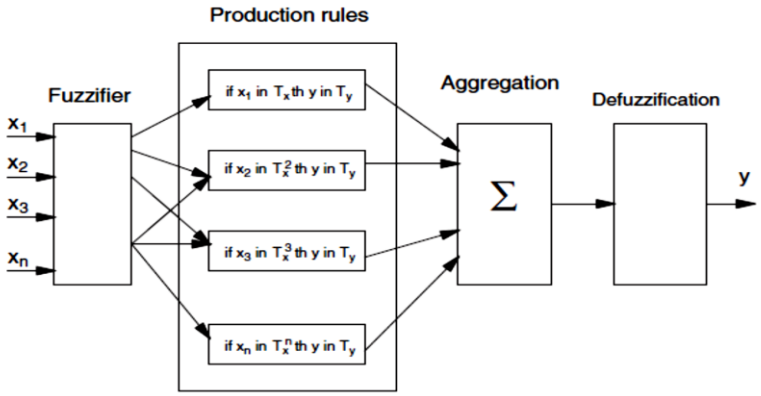


Fig. 3. Fuzzy inference system: fuzzification, rule application, and defuzzification process.

1.6 | Fuzzy Inference System

Two inputs (x, y).

One output (z).

Rule 1: if x is A3 or y is B1, then z is C1.

Rule 2: if x is A2 and y is B2, then z is C2.

Rule 3: if x is A_1, then z is C_3.

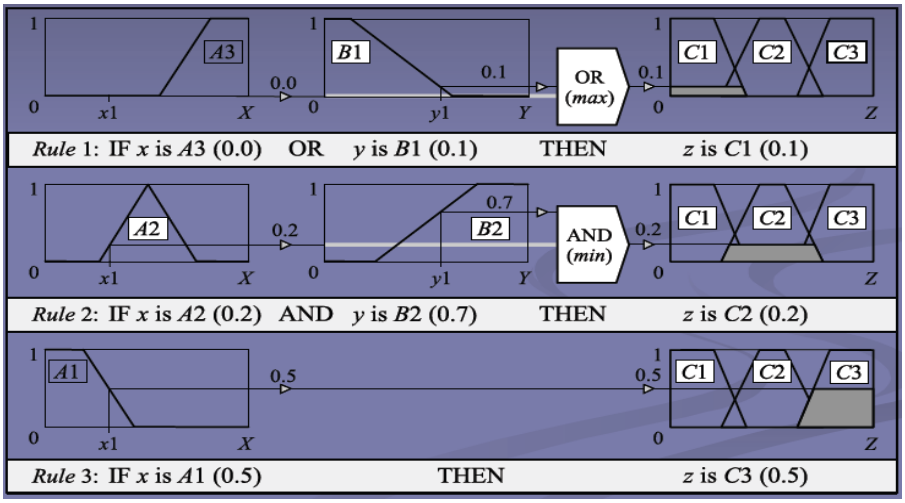


Fig. 4. Fuzzy rule-based system: evaluation of input conditions with OR/AND logic and resulting output classification.

1.7 | Previous Research

Fuzzy sets were proposed by Zadeh [4] in his paper entitled none other than fuzzy sets. This paper laid the foundation for all fuzzy logic, followed by mathematically defining fuzzy sets and their properties. From Zadeh's paper, the definition of a fuzzy set is to let X be a space of points, with a generic element of X denoted by x. Thus, X ={x}. Professor Ebrahim Mamdani (1975) of London University built one of the first fuzzy systems to control a steam engine and boiler combination. He applied a set of fuzzy rules supplied by experienced human operators. Kosko [2] introduced FCMs as fuzzy-graph structures for representing causal reasoning. Their fuzziness allows hazy degrees of causality between hazy causal concepts.

Axelrod [5] proposed cognitive maps as a formal tool for decision-making. He used the matrix representation of the directed graph to represent and study social scientific knowledge. His FCM is signed digraphs. Nodes are variable concepts, and edges are causal connections. Kandasamy et al. [3] has constructed the Fuzzy Relational Models and FCMs and has effectively used the Fuzzy Models in analyzing the problems of displaced persons, school drop-outs, AIDs patients, Dalits, Rag pickers, PWDs, etc.

Malhotra et al. [6] estimated the effects of gold plating, and we designed a tool based on FCM. With the help of this tool, the developer can know the effects of doing gold plating on the project, and based on the tool's output, the developer can make subsequent decisions regarding the project. Murungwen et al. [7] found that the interactive nature of FCMs reveals hidden knowledge and insights that improve the understanding of the complexity of livelihood systems in a way that stakeholders better appreciate.

Yang et al. [8] propose research one kind of two-layer True-Tree FCM (TTFCM) to model the system with the relational data in the form of E-R schema through analyzing the relational database and the multi-relational characteristic. The TTFCM includes one high-level FCM and many low-level FCMs, forming a two-level tree. Also, their analysis of vulnerability using the FCM method showed that policy issues, such as changing situations at borders, can strongly aggravate vulnerability to climate change by increasing the drought sensitivity of livelihoods.

Kannan et al. [9] studied the fuzzy Floyd Warshall and fuzzy rectangular algorithms to find the shortest path. Broumi et al. [1] made an efficient approach for solving time-dependent shortest path problem under the fermatean neutrosophic environment. Vidhya et al. [10] proposed a novel method for finding the shortest path with two objectives under trapezoidal intuitionistic fuzzy arc costs. Prakash et al. [11] presented an optimal solution for a fully spherical fuzzy linear programming problem. Saraswathi [12] developed a fuzzy-trapezoidal DEMATEL approach for solving uncertain decision-making problems.

Dharmaraj et al. [13] have applied a modified Gauss elimination technique for Separable Fuzzy Nonlinear Programming Problems. Vidhya et al. [10] investigated the A* search algorithm for the shortest path under an interval-valued Pythagorean fuzzy environment. Saraswathi and Mahalakshmi [14] solved a new approach for solving the minimal flow, which was the shortest. The route, maximal flow and the critical path using network.

Saraswathi et al. [15] used a triangular fuzzy clustering model under uncertainty. Prakash and Saraswathi [16] studied a novel approach for a multi-objective linear programming model under a spherical fuzzy environment and its application. Saraswathi and Karthick [17] used a neutrosophic linear fractional programming problem using the denominator objective restriction method. Saraswathi and Nedumaran [15] developed a comparative study to find the critical path using triangular fuzzy numbers.

2 | Preliminaries

Definition 1. If X is a universal set and $x \in X$, then a fuzzy set $\tilde{A}$ defined as a collection of ordered pairs

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \epsilon X\},$$

where $\mu_{\tilde{A}}(x)$ is called the membership function that maps X to the membership space M.

Definition 2. A fuzzy set $\tilde{A}$ defined on X is called a normal fuzzy set if there exists at least one $x \in X$ such that $\mu_{\tilde{A}}(x) = 1$.

Definition 3. Given a fuzzy set $\tilde{A}$ defined on 'X' and any $\alpha \in [0,1]$ the α–cut is denoted by $\tilde{A}(\alpha)$ and is defined as

$$\tilde{A}(\alpha) = \{x, \mu(x) \geq \alpha, \alpha \in [0,1]\}.$$

Definition 4. An FCM is a directed graph with concepts like policies, events, etc, as nodes and causalities as edges. It represents a casual relationship between concepts.

Definition 4. When the FCM nodes are fuzzy sets, they are called fuzzy nodes.

Definition 5. FCMs with edge weights or causalities from the set {-1, 0, 1} are simple -FCMs.

The topology of FCM is a following graph in which $C = \{C1, C2, ..., Cn\}$ are a set of nodes representing concepts. $E = \{<C1,C2> | C1, C2 \in C\}$ are oriented arcs denoting the cause and effect relationship that one concept has on the others, $W = \{Wi\,j \mid Wi\,j$ is the weight value of the interconnection $<Ci,Cj>\}$, $Wi\,j$ belongs to the interval [-1,1]. W in FCM is a square matrix of $n \times n$, shown below.

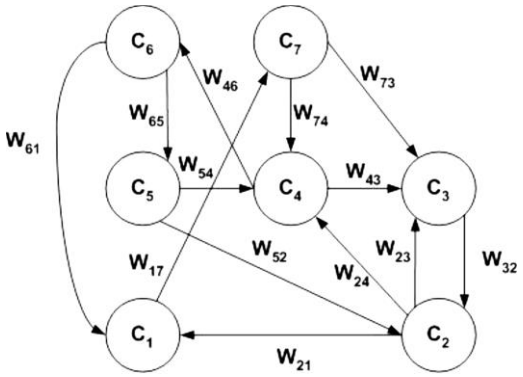


Fig. 5. A simple FCM.

Definition 6. The edges e_{ij} take values in the fuzzy casual interval [-1, 1]. $e_{ij} = 0$ Indicates no causality, $e_{ij} > 0$ indicates casual increase C_j increases as C_i increases (or C_j decreases as C_i decreases). $e_{ij} < 0$ Indicates casual decrease or negative causality. C_j Decreases as C_i increases (and or C_j increases as C_i decreases). Simple FCMs have edge values in {-1, 0, 1}.

Then, if causality occurs, it occurs to a maximal positive or negative degree. Simple FCMs provide a quick first approximation to an expert stand or printed causal knowledge. If an increase (or decrease) in one concept leads to an increase (or decrease) in another, then we give the value 1. If there exists no relation between the two concepts, the value 0 is given. If an increase (or decrease) in one concept decreases (or increases) another, then we give the value 1. Thus, FCMs are described in this way.

Consider the nodes or concepts $C_1, C_2, ...C_n$ of the FCM. Suppose the directed graph is drawn using edge weight $e_{ij} \in \{-1, 0, 1\}$. thus matrix E be defined by $E = (e_{ij})$, where the e_{ij} is the weight of the directed edge C_iC_j.. E is called the adjacency matrix of the FCM, also known as the connection matrix of the FCM. It is important to note that all matrices associated with an FCM are always square matrices with diagonal entries as zero.

$$\begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_{n-1} \\ C_n \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & \cdots & \cdots & C_n \end{array} \\ \begin{pmatrix} 0 & W_{12} & \cdots & \cdots & W_{1n} \\ W_{21} & 0 & \cdots & \cdots & W_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ W_{(n-1)1} & \cdots & \cdots & 0 & W_{(n-1)n} \\ W_{n1} & \cdots & \cdots & W_{n(n-1)} & 0 \end{pmatrix} \end{array}$$

Fig. 6. The weight matrix of FCM.

Definition 7. Let $C_1, C_2, ... C_n$ be the nodes of an FCM. Let $A = (a_1, a_2, ..., a_n)$, , where $a_i \in \{0,1\}$. A is called the Instantaneous state vector, and it denoted the on-off position of the node at an instant $a_i = 0$ if a_i is off and $a_i = 1$ if a_i is on, where 1, 2, … ,n.

It is implemented in two steps:

I. The concepts (N) have to be provided by medical experts and/or guidelines that sufficiently describe the decision making task, including the input and the output knowledge. Each concept is modelled as a variable Ci, i=1, 2, ..., n that can take fuzzy or discrete values according to the problem data. The fuzzy values express the degree to which the concepts occur.

II. The connections between the concepts and their strengths should also be assigned by medical guidelines and/or physicians' knowledge using if-then rules. These fuzzy sets express the degree to which a concept Cj influences another concept Ci, i=1, 2, ..., n, j=1, 2, ..., n.

Definition 8. Let $C_1, C_2, ..., C_n$ be the nodes of an FCM. Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}$, ..., $\overrightarrow{C_iC_j}$, be the edges of the FCM $(i \neq j)$. Then, the edges form a directed cycle. An FCM is said to be cyclic if it possesses a directed cycle. An FCM is said to be acyclic if it does not possess any Directed cycle.

Fig. 7 reflects the process shown in the diagram, where multiple inputs (C1, C2, ..., Cn) are combined using weights (W1, W2, ..., Wn) to compute a final aggregated output (C).

$$C_i^{(k+1)} = f\left(C_i^{(k)} + \sum_{\substack{j=1 \\ j \neq i}}^{N} C_j^{(k)} \cdot W_{ji} \right)$$

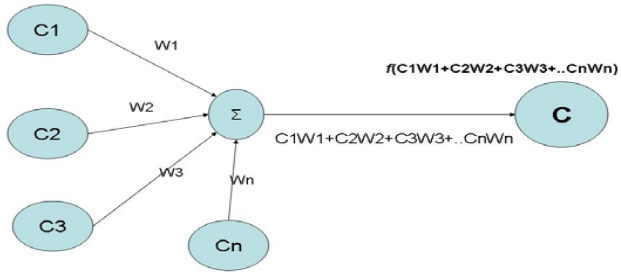


Fig. 7. Weighted sum model for aggregating multiple criteria: calculation of combined output using fuzzy inputs.

Definition 9. Let $\overrightarrow{C_1,C_2}$, $\overrightarrow{C_2C_3}$ ... $\overrightarrow{C_iC_j}$, be a cycle when C_i is switched on and if the causality flows through the edges of a cycle and if it again causes C_i, we say that the dynamical system goes round and round. This is true for any node C_i, for i=1, 2 ... n. The equilibrium state for this dynamical system is called the Hidden pattern.

Definition 10. If the equilibrium state of a dynamical system is a unique state vector, then it is called a fixed point. Consider a FCM with C_1, C_2, ... C_n as nodes. For example, let us start the dynamical system by switching on C_1. Let us assume that the FCM settles down with C_1 and C_2 on, i.e., the state vector remains as (1, 0, 0, … , 0, 1). This state vector (1, 0, 0, …, 0, 1) is called the fixed point.

Definition 11. If the FCM settles down with a state vector repeating in the form $A_1 \to A_2 \to ... A_1 \to A_1$. Then, this equilibrium is called the Limit cycle.

Definition 12. A finite number of FCMs can be combined together to produce the joint effect of all the FCMs. Let E_1, E_2, ... E_p be adjacency matrices of the FCMs with nodes C_1, C_2, ... C_n. Then, the combined FCM is obtained by adding all the adjacency matrices E_1, E_2, ... E_p. We denote the combined FCM adjacency matrix by $E = E_1 + E_2 + ... + E_p$.

Definition 13. Advantages and disadvantages of FCM: the main advantage of this method is that it is simple. It functions on an expert's opinion. When the data is unsupervised, the FCM comes in handy. This is the only known fuzzy technique that gives the hidden pattern of the situation, as we have a very well-known theory that states that the strength of the data depends on the number of experts' opinions; we can use combined FCMs with several experts' opinions.

At the same time, the disadvantage of the combined FCM is when the weights are 1 and -1 for the same C_i C_j, we have the sum adding to zero; thus, at all times, the connection matrices $E_1, E_2, ... , E_k$ may not be conformable for addition.

Combined conflicting opinions tend to cancel out and are assisted by the strong law of large numbers. A consensus emerges as the sample opinion approximates the underlying population opinion. This problem will be easily overcome if the FCM entries are only 0 and 1. The knowledge of guidelines (instead of experts' knowledge) can be easily converted to a number of if-then rules, which are used to construct the FCM model.

Applications of FCM in various field: modelling-knowledge representation, decision making, enterprise resource management, socio-economic systems, engineering & technology management, adaptation and learning, classification tasks, robots and control, political and social fields, military planning, production systems, prediction capabilities, ecology and environmental.

4 | Methods to Propose

We have taken the following three concepts and twenty problems. Using a linguistic questionnaire, the expert's opinion was arrived at by the NGO organization by administering the same to 100 transgender people, 10 parents, and three NGO leaders. To analyze the major reasons for transgender problems, use FCMs. The following concepts are taken as the main nodes of our problem listed below.

The survey was based on the following questions:

I. What is your perspective of transgender?

II. When did you realize that you aren't the person with the sex that people claimed you were?

III. Are you happy about what you are right now?

IV. Is the society accepting you are right now?

V. Have you even being humiliated (explain if any)?

VI. If you ever have a chance to change your gender, will you (If yes, it is miserable)?

VII. What is your sex preference?

VIII. Are you financially supported?

IX. If you can, will you give birth to a baby?

X. How would you react if your baby grew up as a Tran's man or a Tran's woman?

XI. What would you say to the transgender out there?

XII. What would you say to the people who realized their gender doesn't go with their sex but are afraid to express their self?

The following problems are listed based on our interview and survey through Transgender view:

T_1: penury (poverty).

T_2: hormones disorder.

T_3: sexually affected.

T_4: public cheating.

T_5: affected by HIV/AIDS.

The following problems are listed based on our interview and survey through NGO - Leader View:

N_1: isolated from public.

N_2: unawareness.

N_3: malnutrition.

N_4: bad companionship.

N_5: deprived from facilities.

N_6: forced to beg.

N_7: not allowed in decision-making.

The following problems are listed based on our interview and survey through parents View:

P_1: without parents.

P_2: away from family.

P_3: no future.

P_4: lack of education.

P_5: no property.

P_6: loss of identity.

P_7: depression.

P_8: no shelter.

4.1| Method of Determining the Hidden Pattern

Here, we follow the seven steps of Calculations:

Step 1. Let $C_1, C_2, \ldots, C_n$ be the nodes of an FCM with feedback. Let E be the associated adjacency matrix.

Step 2. Let us find the hidden pattern when C_1 is switched on.

Step 3. When an input is given as the vector $A_1 = (1,0,0,...,0)$, the data should pass through the relation matrix E. This is done by multiplying A_1 by the matrix E.

Step 4. let $A_1E = (a_1,....a_n)$ with the threshold operation by replacing a_i by 1 if $a_i > k$ and a_i by 0 if $a_i < k$ (k is a suitable positive integer).

Step 5. We update the resulting concept. The concept C_6 is included in the updated vector by making the sixth coordinate as 1 in the resulting vector.

Step 6. Suppose $A_1E \to A_2$, then consider A_2E and repeat the same procedure.

Step 7. This procedure is repeated till we get a limit cycle or a fixed point.

4.2 | Case (I): The Following is the Directed Graph Obtained based on the First Experts (Transgenders) View

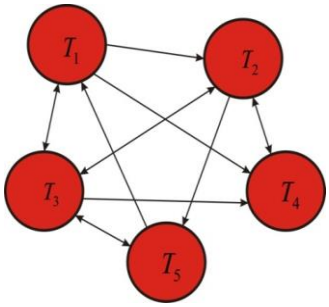


Fig. 8. Directed graph based on the first experts.

The related directed matrix of A is given below:

$$T = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \end{bmatrix}.$$

4.3 | Case(Ii): the Following is the Directed Graph Obtained based on the Second Expert (Parents of Transgender) View

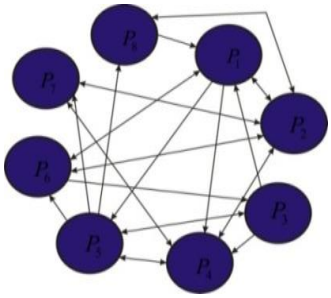


Fig. 9. Directed graph based on the second expert.

The related directed matrix of B is given below:

$$P = \begin{bmatrix} 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

4.4|Case (III): the Following is the Directed Graph Obtained based on the Third Experts (NGO Leaders of Transgender) View

Therefore, the directed graph is given below:

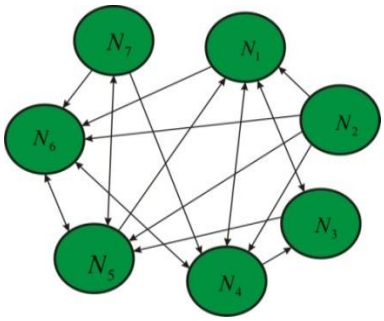


Fig. 10. Directed graph based on the third experts.

The directed matrix of N is given below.

$$N = \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}.$$

4.5|Combined FCM M=T+P+N to Get the Collective Opinion of the above Three Experts

We follow the following procedure. The combined directed graph is above below:

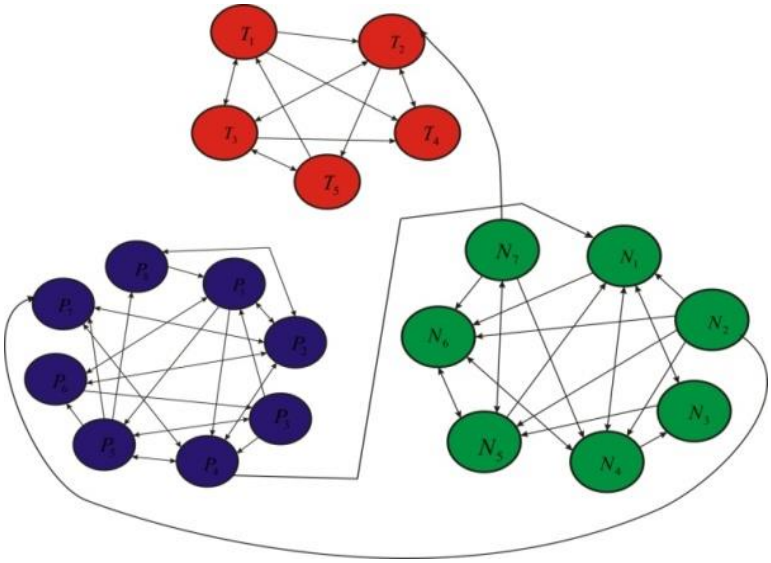


Fig. 11. Collective opinion of the above three experts.

Combined Matrix M=T+P+N.

$$M=\begin{array}{c|ccccccccccccccccccc}
 & T_1 & T_2 & T_3 & T_4 & T_5 & P_1 & P_2 & P_3 & P_4 & P_5 & P_6 & P_7 & P_8 & N_1 & N_2 & N_3 & N_4 & N_5 & N_6 & N_7 \\
\hline
T_1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
T_2 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
T_3 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
T_4 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
T_5 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
P_1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
P_2 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
P_3 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
P_4 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
P_5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
P_6 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
P_7 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
P_8 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
N_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\
N_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\
N_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\
N_4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 \\
N_5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 \\
N_6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\
N_7 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0
\end{array}.$$

Results of CFCMs: M=T+P+N.

$$T=[0\,1\,0\,0\,0\,1\,0\,0\,0\,0\,0\,0\,0\,0\,0\,0\,0\,0\,0]$$
$$\Rightarrow T\times M=[0\,0\,1\,1\,1\,0\,1\,0\,1\,1\,1\,0\,0\,0\,0\,0\,0\,0\,0]$$
$$\mapsto[0\,1\,1\,1\,1\,1\,1\,0\,1\,1\,1\,0\,0\,0\,0\,0\,0\,0\,0].$$

$$T_2\times M=[2\,4\,3\,3\,2\,4\,5\,0\,4\,5\,3\,0\,0\,0\,1\,0\,0\,0\,0]$$
$$\mapsto[1\,1\,1\,1\,1\,1\,1\,0\,1\,1\,1\,0\,0\,0\,1\,0\,0\,0\,0].$$

$$T_3\times M=[2\,4\,3\,3\,2\,4\,5\,0\,4\,5\,3\,1\,0\,1\,1\,0\,1\,1\,1\,0]$$
$$\mapsto[1\,1\,1\,1\,1\,1\,1\,0\,1\,1\,1\,1\,0\,1\,1\,0\,1\,1\,1\,0].$$

$T_4 \times M = [2\ 4\ 3\ 3\ 2\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 0\ 0\ 0\ 0]$
$= [2\ 4\ 3\ 3\ 2\ 2\ 4\ 2\ 4\ 2\ 4\ 3\ 3\ 4\ 1\ 2\ 3\ 2\ 4\ 1]$
$\mapsto [1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1].$

$T_5 \times M = [2\ 4\ 3\ 3\ 2\ 4\ 5\ 2\ 5\ 3\ 3\ 4\ 3\ 5\ 1\ 2\ 4\ 4\ 5\ 1]$
$\mapsto [1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1].$

The symbol denotes after thresholding and updating.

5 | Conclusion of CFCMs

If T_2- Hormones disorder and P_1- Without parents are in the ON state, all the nodes in problems come up to the ON state. Hence, it is clearly seen that T_1- Penury (Poverty), T_3- Sexually affected, T_4- Public cheating, T_5- Affected by HIV/AIDS, N_1- Isolated from public, N_2- Un awareness, N_3- Mal nutrition, N_4- Bad companionship, N_5- Deprived from facilities, N_6- Forced to beg, N_7- Not allowed in decision making, P_2- Away from family, P_3- No future, P_4- Lack of education, P_5- No property, P_6- Loss of identity, P_7- Depression, and P_8- No shelter are also on state.

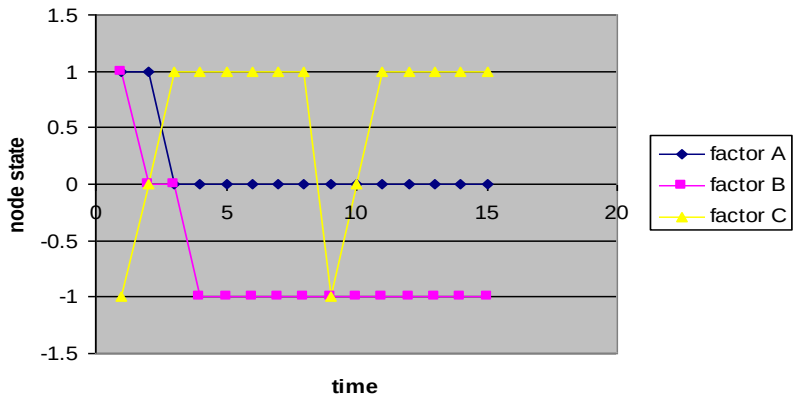


Fig. 12. FCM iterative behavior.

6 | Suggested Policy Measures

I. Early diagnostic health centres could be established by the social welfare ministry to opt for corrective surgery.

II. Reservation in private/public sectors to enforce employment and education.

III. Alternative occupation/skill development centres/counselling centres should be enforced by NGOs.

IV. Army/Navy/Air Force to think of instating skills of transgenders.

V. Self-help women group of empower with special skills, identify and rehabilitate transgenders.

VI. State policing to train to employ more transgenders with mandatory reservation.

VII. At least one seat should be reserved in parliament for representing the cause of transgender. Their suggestions should be taken in public and nationally.

VIII. They should be accepted in the society with respect and dignity. Their abuse complaints should be taken seriously and acted upon by law and enforcement by NGO's.

IX. No restriction should be made on access to education, health services, public utilities, etc. Employment opportunities should be provided.

X. Opportunities for political participation are to be created. They should be given equal citizenship rights, safety, and security.

6.1 | Findings from Combined Fuzzy Cognitive Maps

T_2- Hormones disorder and P_1-Without parents are the main causes of the problems of the Transgenders using the CFCM Model. Once transgender face Hormone disorders, they are pushed out of their own families and live without parents; they face many issues like the ones stated in the study. The major issue is the presence of a third gender. The Parents feel disgraced and depressed once they find their ward belongs to a third gender. It varies from 0.2 percent to one percent. The family and society should accept them as one among them and look to fulfil their needs instead of pushing them away from their families and societies. As they mostly leave their families at the dawn of adolescent age, sexual urge plays a crucial role in fulfilling their other needs like food, clothing and shelter. They are pushed to sex work or to beg to earn their living. Due to erratic unprotected sex with whomsoever they come across, they fall prey to Sexually Transmitted Diseases (STDs) and/or HIV/AIDs.

6.2 | Suggestions based on Combined Fuzzy Cognitive Maps

Transgender are thus abandoned by their parents at a very early age and so find no other way to come in contact with other Trans -people. They stay away from their families and are forced to cut all relations with relatives. They are often abused by society and made to starve for want of food, shelter, education and, health and allied services. They should be provided with some organization to take care of their rights, and they should be provided with special quotas for jobs, education, and health services. Separate job allotment, like in the military, can effectively solve this problem. Effective policies should be considered for them to face their problem effectively. Wherever possible, corrective surgery can be made free of cost to rectify the hormonal imbalances.

Author Contribution

Appasamy Saraswathi, Seyyed Ahmad Edalatpanah, and Sanaz Hami Hassan Kiyadeh contributed equally to the conceptualization, analysis, and writing of the manuscript. Each author played a significant role in developing the research, discussing the findings, and reviewing the final draft.

Funding

The authors received no external funding for this research.

Data Availability

Data supporting the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest related to this study.

References

[1] Broumi, S. (2024). An efficient approach for solving time-dependent shortest path problem under fermatean neutrosophic environment. *Neutrosophic sets and systems*, *63*(1), 6, 82-94.

[2] Kosko, b. (1986). Fuzzy cognitive maps. *International journal of man-machine studies*, *24*(1), 65–75. DOI:10.1016/S0020-7373(86)80040-2

[3] Kandasamy, W. B. V., Smarandache, F., & Ilanthenral, K. (2007). *Elementary fuzzy matrix theory and fuzzy models for social scientists*. Infinite Study.

[4] Zadeh, L. A. (1965). Fuzzy sets and fuzzy cognitive maps. *Information and control*, *8*(3), 338–353. DOI:10.1016/S0019-9958(65)90241-X

[5] Axelrod, R. (2015). *Structure of decision: the cognitive maps of political elites*. Princeton Legacy Library.

[6] Malhotra, N., Bhardwaj, M., & Kaur, R. (2012). Estimating the effects of gold plating using fuzzy cognitive maps. *International journal of computer science and information technologies*, *3*(4), 4806–4808.

[7] Murungweni, C., van Wijk, M. T., Andersson, J. A., Smaling, E. M. A., & Giller, K. E. (2011). Application of fuzzy cognitive mapping in livelihood vulnerability analysis. *Ecology and society*, *16*(4), 16-30.

[8] Yang, B., & Peng, Z. (2009). Fuzzy cognitive map and a mining methodology based on multi-relational data resources. *Fuzzy information and engineering*, *1*(4), 357–366. DOI:10.1007/s12543-009-0028-7

[9] Kannan, V., Appasamy, S., & Kandasamy, G. (2022). Comparative study of fuzzy Floyd Warshall algorithm and the fuzzy rectangular algorithm to find the shortest path. *AIP conference proceedings*, *2516*(1), 200029. DOI:10.1063/5.0110337

[10] K. Vidhya; A. Saraswathi. (2023). A novel method for finding the shortest path with two objectives under trapezoidal intuitionistic fuzzy arc costs. *International journal of analysis and applications*, *21*, 121. DOI:10.28924/2291-8639-21-2023-121

[11] Prakash, Y., & Appasamy, S. (2023). Optimal solution for fully spherical fuzzy linear programming problem. *Mathematical modelling of engineering problems*, *10*(5). DOI:10.18280/mmep.100511

[12] Saraswathi, A. (2019). A fuzzy-trapezoidal dematel approach method for solving decision making problems under uncertainty. *AIP conference proceedings* (Vol. 2112) AIP Press. DOI: http://dx.doi.org/10.1063/1.5112261

[13] Dharmaraj, B., & Appasamy, S. (2023). Application of a modified gauss elimination technique for separable fuzzy nonlinear programming problems. *Mathematical modelling of engineering problems*, *10*(4), 1481–1486. DOI:10.18280/mmep.100445

[14] Saraswathi, A., & Mahalakshmi, S. (2024). A new approach for solving the minimal flow, shortest route, maximal flow and the critical path using network. *International journal of system design and information processing*, *12*(2), 263–276.

[15] Saraswathi, A., & Nedumaran, P. (2024). Comparative study to find the critical path using triangular fuzzy number. *Journal of computational analysis and applications (JOCAAA)*, *33*(05), 345–354.

[16] Prakash, y., & Saraswathi, A. (2024). A novel approach for multi-objective linear programming model under spherical fuzzy environment and its application. *Journal of intelligent & fuzzy systems*, *46*(2), 3259–3280.

[17] Saraswathi, A., & Karthick, B. (2024). Neutrosophic linear fractional programming problem using denominator objective restriction method. *Dynamics of continuous, discrete and impulsive systems series B: applications & algorithms*, *31*(8), 89–101.